Web Infrastructure for the 21st Century

Pablo Rodriguez
“With 25 years of Internet experience, we’ve learned exactly one way to deal with the exponential growth: Caching”

1997, Van Jacobson
Web Infrastructure: Content Distribution Networks

- 40,000 servers, 900 PoPs, 71 countries
- 300 Gbps

- 25 PoPs, Hundreds of servers per presence
- 1,000 Gbps
Struggled to cope with flash crowd events

Sep 11 attacks
6 fold growth in four years

Source: IDC, 2007
Much today’s Web infrastructure to distribute content has been an after-thought
Roadmap

- Part 1: Locating and Managing Content
- Part 2: Distributing Content
- Part 3: Data Centre Clouds
- Part 4: Clouds for Online Social Networks
Three waves of Networking

1930

1960

1990
Internet Design

- Internet was designed as a thin layer so that ANY application could run on top.

- It was not optimized for any particular application, in particular not for Content.

- And that created some problems…
Where vs What
Container vs Content

- It is a serious mistake to point to the container, not the content

“*I urged them to remove some of the technical mistakes of the language, the predominance of references…*”

*Turing Award lecture, Tony Hoare*

- You have security issues; reasoning issues; you have robustness issues…
Problems…

- **Search**
  - Search relies on links, if content/links change/disappear search suffers

- **Distribution**
  - Routers waste capacity copying the same bits millions of times.

- **Replication**
  - If content is split, it is hard to obtain
Management Problems…

- **Security**
  - Authenticity, Chain of Custody/Transformation, Revocation!

- **Policy**
  - Lack of data control, data embargo, privacy and access rules

- **Traceability**
  - How many hits did my content get?
Content Networking

- Content networking paradigm
  - Van Jacobson

- Content indexed by keys
  - What you want, not where to get it from

- Data is self-certified
  - Secure the data, not the channel

- Storage everywhere
  - Why not adding 1TB to each router
But should it be a Revolution or an Evolution?

IP = the Internet Kernel
Revolution: The Internet as a database?

- Routing is a simple form of searching
- Today you route through paths to reach hosts
- The network could support more complex ways of routing (e.g. find me all files similar to X)
Evolution: Build as an overlay?

- Lots of things to learn from P2P networks
- P2P Naming, DHTs, Chunk retrieval, Swarming
- What if every Web file becomes a P2P Swarm?
Roadmap

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Is the Internet the preferred medium for distributing bulk (delay tolerant) digital content?
Not beyond a certain size …

- e.g. movies, home videos, data backups, data replication

Currently, served by:
- Dedicated networks
- Parcel delivery
10M+ users

1.5 Million DVDs per day
2.5 PB/day!

All US P2P traffic
14 PB/day (cisco)

Postal still carries vast amount of multimedia traffic
How well is the current Internet dealing with large content transfers...?
Current bulk data demand is probably higher than what the Internet can handle
## The Effect of Distance

<table>
<thead>
<tr>
<th>Distance from Server to User</th>
<th>4GB DVD Download Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local: &lt;100 mi.</td>
<td>12 min.</td>
</tr>
<tr>
<td>Regional: 500-1,000 mi.</td>
<td>2.2 hrs.</td>
</tr>
<tr>
<td>Cross continent: -3,000 mi.</td>
<td>8.2 hrs.</td>
</tr>
<tr>
<td>Multi-continent: -6,000 mi.</td>
<td>20 hrs.</td>
</tr>
</tbody>
</table>

[Tom Leighton, 2008]
The further we travel in the network, the more bottlenecks we will see

... and they are time dependant
Non-overlapping valleys

Available rate

Sender in LAT Receiver in EU or China

sender
receiver
The Real Problem

Internet:

- short burst/instantaneous ✔
- bulk/delay tolerant ✗
Current Internet
Roadmap

- Part 1: Locating and Managing Content
- Part 2: Distributing Content
- Part 3: Data Centre Clouds
- Part 4: Clouds for Online Social Networks
Clouds: Hosting Web Content and Services

- **Economies of scale** (Hamilton, 2008)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Cost (medium scale)</th>
<th>Cost (large scale)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network</td>
<td>$95 / Mbps / month</td>
<td>$13 / Mbps / month</td>
<td>~7x</td>
</tr>
<tr>
<td>Storage</td>
<td>$2.20 / GB / month</td>
<td>$0.40 / GB / month</td>
<td>~6x</td>
</tr>
<tr>
<td>Admin</td>
<td>≈140 servers/admin</td>
<td>&gt;1000 servers/admin</td>
<td>~7x</td>
</tr>
</tbody>
</table>

- **Virtualization technologies**

- **Off-peak capacity**
Data Centers:
100,000s of servers spread over
100,000s of square feet drawing
10 to 20MW of power
Cooling and Electricity are becoming more important than server’s cost
Highly Distributed Data Centers
Challenges to host Applications

Some candidates for distributed data centers:

- P2P Video Delivery
- Voice/Video Conferencing
- Multi-player games

- Online Social networks…?
Roadmap

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- OSN are changing the way people interact on the Web

- But also changing its infrastructure

- The Cloud needs to become more “socially” aware
Some quick facts

- Facebook has grown from 100M to 200M in less than 8 months
- Twitter Feb to March growth of 1,230%
- The first twitter celebrity Ashton Kutcher with 1MM+ followers.
- Oprah got 100K+ followers on Twitter in 4 hours
- Nielsen Online’s latest research shows that OSN is now more popular than email
The Internet

The Web

P2P

OSN
New Design Challenges

- Can the social networks predict which videos are likely to be seen by consumers, at what times, where?

- How to design infrastructure to empower OSN celebrities to have their own broadcast channel?

- How do you handle security issues? OSN celebrities could produce DDoS over any website.
Hosting Social Networks in Distributed Clouds

- One operation results in a social cascade
- LinkedIn: 22M users, Facebook with 200M+
- Data structures no longer fit in the memory of a single server
- Data partition is a must:
  - How to minimize inter data center communication
  - How to ensure consistency and small latencies
Roadmap

- Part 1: Locating and Managing Content
- Part 2: Distributing Content
- Part 3: Data Centre Clouds
- Part 4: Impact of Online Social Networks
Final Thoughts

- Things are getting more complex, is it time to rethink some designs and move into firmer grounds?

- Going forward, do we need to think of the Web infrastructure design to be more embedded with the Internet design? Can developments at these two levels move independently?

- What elements are matured enough to be pushed into the lower layers and become basic services, like routing is? (e.g. locating content, content distribution)
Conclusions

- The Web has often pushed the Internet infrastructure to its limits
- Locating, Managing, Distributing content still pose challenges
- Both Social Networks and Greener Clouds will re-shape the Web infrastructure, once more…